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Health and Economic Impacts of Mycotoxins in Foods in Latin America and the Caribbean

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Abstract

Myotoxins, including aflatoxins, trichotehecenes, zearalenone, fumonisins deoxynivalenol and ochratoxin A, are potent toxic fungal metabolites that contaminate staple crops and pose serious health problems to man and animals when contaminated foods or feeds are ingested. In acute mycotoxicosis, severe symptoms of illness such as acute liver damage, jaundice, vomiting, high fever and hemorrhage can occur very quickly after consumption of contaminated foods, and can result in death. Chronic dietary intake of mycotoxins in humans and animals has been related to development of cancer, growth retardation, micronutrient deficiency and impairment of the immune system. The Food and Agricultural Organization estimates that 25 % of the world's food crop is contaminated with mycotoxins. While many countries in Europe and North America enforce regulations that control the levels of mycotoxins in foods, efforts to educate the public on the dangers of mycotoxins and to reduce the levels of aflatoxin contamination in foods in Latin American and Caribbean (LAC) countries have been rather weak. A number of crops (maize, wheat, coffee, soybeans, barley, sunflower, groundnuts, tree nuts, cocoa, root tubers and dairy products) that are produced and consumed in LAC countries are highly susceptible to fungal contamination and mycotoxin production and pose health problems for the populace. Mycotoxins also cause serious economic and financial losses to domestic food producers and exporters in LAC. In this paper, we review reports of mycotoxin contamination in crops and food products in LAC and consider the economic and health impacts of mycotoxin contamination in foods to these countries.

Keywords: mycotoxins, health, economic impact, Latin America, Caribbean

Introduction

Mycotoxins are naturally occurring fungal toxins that cause major problems to food safety worldwide (FAO, 2003). They attract worldwide attention because of the significant economic losses that they cause and their impact on human and animal health (Wu, 2004). Common mycotoxins that affect food commodities include: aflatoxins (produced mainly by *Aspergillus* species) in corn, peanuts and many other commodities; ochratoxin A (produced by *Aspergillus* and *Penicillium* species) in barley, wheat, coffee, grapes and many other commodities; Fumonisin B1 (produced by *Fusarium* species) in corn; deoxynivalenol (DON, produced by *Fusarium* species) in wheat, corn and barley; zearalenone (produced by *Fusarium* species) in corn and wheat, and ergot alkaloids (produced by *Claviceps, Penicillium, Aspegillus and Rhizopus* species) in wheat and rye (Peraica et al. 1999). Mycotoxins may also be found in beer and wine resulting from the use of contaminated barley, other cereals, and grapes in their production. These mycotoxins also enter the human food chain via meat or other animal products such as eggs, milk and cheese as a result of livestock being fed contaminated feed.

Mycotoxins pose serious problems to human and animal health. They cause a variety of short-term (acute) as well as long-term (chronic) adverse health effects. Acute aflatoxicosis occurs when moderate to high levels of aflatoxins are consumed and may result in hemorrhage, acute liver damage, rapid progressive jaundice, edema of the limbs, alteration in digestion, absorption and/or metabolism of nutrients, high fever, vomiting, swollen livers and possibly death (Fung and Clark, 2004; CDC, 2004; Ngindu et al. 1982; Krishnamachari et al. 1975). Chronic dietary intake of low to moderate levels of aflatoxins by humans and animals has been shown to be related to the development of cancer (Omer et al. 1998; Peers et al. 1976; Peers et al. 1987; Wild et al. 1992), impaired food conversion (Shane, 1993), growth retardation (Gong et al. 2002; Gong et al. 2004), micronutrient deficiency (Pimpukdee et al. 2004; Abbas and Ali, 2001; Glahn et al. 1991; Kalorey et al. 1996; Mocchegiani et al. 2001; Chen et al. 2000) and impairment of the immune system (Ali et al. 1994; Pestka and Bondy 1994; Pier 1986; Venturini et al. 1996; Jiang et al. 2005). Aflatoxin and ochratoxin have been shown to be immunosuppressive, mutagenic, teratogenic and carcinogenic agents. In addition, aflatoxin has been shown to be encephalopathic and ochratoxin has been shown to be nephrotoxic, Deoxynivalenol (DON, vomitoxin) is immunosuppressive and causes nausea and vomiting. Fumonisins cause abdominal pain, diarrhea, oesophegeal cancer and nephropathy, and ergot causes gangrenous ergotism, gastroenteritis, blindness, paralysis and encephalopathy (Peraica et al. 1999).

Economic Effects of Mycotoxins Worldwide

Worldwide, substantial quantities of food grains are affected by mycotoxins each year. In actuality, it has been estimated that about 25% to 50% of the world's food crops are affected by mycotoxins (Miller, 1995). This includes 16 million tons of maize, 12 million tons of rice, 1.8 million tons of groundnuts, 378,000 tons of sorghum and millet, 3.7 million tons of copra and 2.3 million tons of soybeans. Estimates from sample data from the Food and Drug Administration (FDA) show that crop losses from mycotoxins (aflatoxin, fumonisin and DON) in maize, wheat and peanuts in the United States average $932 million annually. Additionally, annual losses averaging 466 million) were incurred by the US in efforts to prevent or reduce mycotoxin contamination (CAST, 2003). The study estimated livestock losses due to mycotoxins to be about US $6 million.

Mycotoxins and Agricultural Products in Latin America

In 2003, world agriculture trade was valued at greater than $500 billion and 33% of this amount came from developing countries (FAO, 2006) including countries in Latin America and the Caribbean (LAC). The main source of development resources in the majority of countries in LAC is derived from farming and a growing tourism industry. For example, 40% and 48% of total exports from South and Central America, respectively, are agricultural in nature (PAHO, 2005). The major Latin American agricultural crops, which include maize, wheat, coffee, cotton, soybeans, barley, sunflower, peanuts, cocoa, meat, and dairy products, are all highly susceptible to mycotoxin contamination. Peanuts, peanut products and maize are the main commodities contaminated with aflatoxin in Latin America. Other mycotoxins such as zearalenone, T-2, DON, penicillic acid and ochratoxin have been detected in maize in the region. Other staple foods such as black beans, red beans, wheat, sorghum and rice are also affected by mycotoxins. However, studies and statistics available on the actual economic loss due to mycotoxins in the Latin America and Caribbean region are limited and are mostly restricted to the study of aflatoxin. In Brazil, private feed companies have undertaken to control levels of mycotoxins in animal feed since these toxins reduce the efficiency of livestock production. The costs of mycotoxin analyses is estimated to be about US $55,900 in capital investment and between US $0.02 and $0.06 per ton of feed per month (Salay, 2003). Brazil produced 35.3 million tons of maize in 2001-2002 about 65% of which was used for animal feed.

Reports of mycotoxin contamination in crops in Latin

America and the Caribbean

The bulk of mycotoxin research in Latin America and the Caribbean has been conducted on maize and specifically on aflatoxins. The main grain exporting countries in South America that conduct research on aflatoxins are Brazil, Argentina, Colombia, Venezuela and Uruguay.

Few studies have been conducted on aflatoxins in Bolivia, Chile, Ecuador, Peru, Costa Rica and Mexico and no studies have been conducted on aflatoxins in French Guyana, Guyana, Paraguay and Suriname. In the Caribbean, a study that was conducted in Haiti in 1982-1984 showed high levels of aflatoxin in maize (Justafort, 1986). Haiti produces maize to meet the needs of approximately 50% of its population.

The most toxic of the aflatoxins (B_1, B_2, G_1, G_2) is aflatoxin B_1 (AFB_1) which is also the most potent hepatotoxic and hepatocarcinogenic mycotoxin (Gourama and Bullerman, 1995). Zuber et al. (1986) reported on AFB_1 levels in maize samples from Colombia, Costa Rica, Bolivia, Brazil, Ecuador and Mexico. No samples from Ecuador were found to be positive and 8% of samples from both Bolivia and Brazil had trace amounts of AFB_1. However, much higher percentages of maize samples from Colombia (83%) and Costa Rica (100%) were contaminated with AFB_1. The AFB_1 levels in maize from Colombia and Costa Rica ranged from 11-209 ng/g^{-1} and 2-26 ng/g^{-1} respectively. Fifty-eight percent of maize samples from Mexico were contaminated with AFB_1 at levels ranging from 3-48 ng/g^{-1}. Mora (1986) reported that approximately 50% of 400 white maize samples tested in Costa Rica were contaminated with aflatoxins. Most samples showed levels from 100-200 ppb and some had levels as high as 800 ppb. Calderon (1986) reported on the occurrence of aflatoxin in cereal/grain samples from government storage facilities (silos) in El Salvador. Aflatoxin was detected in 72% of 98 silos sampled. Approximately 70% of red bean (<0.01-63 ppb) and 92% of black bean (<0.01-79 ppb) samples were positive for aflatoxin. With regard to maize, 50% of white maize samples (<0.01-22 ppb) and both of two yellow maize (<0.01 ppb) samples tested were positive for aflatoxin. All of four white sorghum samples were also positive for aflatoxin (<0.01-28). Samples of agricultural products that were tested in El Salvador in 1983 and 1984 showed that 60% of cellulose materials (19.75-100.6 ppb), 54% of protein materials (13.55-209.7 ppb) and 75% of carbohydrate materials (24.56-332.7 ppb) were positive for aflatoxin.

The mycotoxins, aflatoxin and zearalenone, were found in 7-34% of maize samples examined in 1981-1983 in Argentina (Planes de Banchero, 1986). The aflatoxin levels in the samples ranged from 2-64 ppb and zearalenone levels ranged from 30-912 ppb. Aflatoxin was also found in 24% of maize flour samples studied in 1984 but these samples were negative for zearalenone.

A very significant study was

conducted on mycotoxins in maize and tortillas collected from 50 *Molinos* and *Tortillerias* in Mexico (Torreblanca, 1986). This study showed that 72% of either maize or tortilla samples were positive for AFB_1 with levels ranging from 0-500ppb. Zearalenone was found in 24% of maize or tortilla samples. Tortillas contained zearalenone at 4.23 ppm. AFB_1 and AFB_2 were found in tortillas made from maize after nixtamalization and baking. Forty percent of tortillas also contained DON. Maize accounts for nearly 50% of the food consumed annually in Mexico and is the main source of food among the lower socioeconomic groups The average daily per capita consumption of tortillas in Mexico is estimated to be ten (Comision Nacional, 1977). Therefore, the findings of this study by Torreblanca (1986) suggest that there is significant human mycotoxin exposure through food in Mexico with undetermined health effects. Reports of high losses of sorghum crop due to ergot have been made from Southern Tamaulipos and surrounding areas in the adjacent state of Mexico. These reports also suggest that there is widespread human mycotoxin exposure through food in Latin America. However, the health effects of chronic mycotoxin exposure have not been assessed.

There is a lack of published data on acute and chronic human aflatoxicosis in Latin America. A study conducted by Lopez et al. (1977) in Argentina showed 0.47ng/ml AFB_1 in one of thirteen blood samples from donors with hepatic diseases. In Brazil, Hass et al. (2003) used the biomarker approach and determined AFB_1-albumin adduct levels in 50 blood samples. AFB_1-albumin adduct levels ranged from zero to 57.3 pg/mg blood (mean = 14.9 pg/mg), and 62% of blood samples were positive.

Additional and large scale studies need to be conducted in LAC countries to determine human aflatoxin exposure and the resulting health effects.

Ochratoxin A (OTA) in Grapes and Dried Vine Fruits in South America

South America produces 6.6% of grapes and 10% of wine worldwide (Chulze et al. 2006). Argentina produces 58.5% of this amount and is the fifth largest wine producing country worldwide. Chile produces 21% and Brazil produces 11% of wine in the region. Information on OTA in South America is limited. *Aspergillus* species have been isolated from wine grapes in Argentina and Brazil (41–81% of isolates produced OTA). Low levels of OTA have been found in grape juices and wine from Brazil, Argentina and Chile. A mycobiota survey from wine grapes in Argentina showed high levels of fungal species (*Alternaria alternate* and *Aspergillusn nigri*) that produce OTA (Magnoli et al. 2003). Another study conducted in Argentina showed that about 83% of *A. carbonarius* isolates from dried vine fruits produced OTA, with levels ranging from 2 to 5200 ng (Magnoli et al. 2004).

Wines from the LAC region are exported to the United States and

Europe, and generate significant amounts of foreign currency to the region. The wine industry is more important to the Latin American countries than the Caribbean islands since wines from the Caribbean countries are made from imported material, or are rebottled in the Caribbean, whereas the wines from the Latin American countries are manufactured from raw products. Wines with a given level of ochratoxins are refused entry to the US. These products are either resold at a lower price to other countries or are destroyed. The exact quantity of products that is affected is unknown. However, based on given levels of ochratoxins found in wine in the area we were able to simulate the likely financial losses to the area from 1994 to 2006 if all wines contaminated with those levels of ochratoxins were destroyed. In Figures 1 and 2 we estimate the likely financial losses from the export of wines from Caribbean and Latin American countries to the US if we assume a 2.5 %, 5.0 % and 10.0 % level of contamination due to ochratoxins. We show that there is great fluctuation in losses of revenues over the period from the Caribbean countries with the losses peaking in 1995 and 1998 and then remaining rather constant from 1999 to 2006 (Figure 1). For the Latin American countries we show increasing losses with time and the peak in 2006 (Figure 2). This is partly due to increased levels of exports over time.

Coffee is another major export crop for the Latin American countries to the US but not for the Caribbean countries. Jamaica and Haiti are the only Caribbean countries exporting significant amounts of coffee to the U.S., most of which is through irregular marketing channels. Figure 3 shows the likely financial losses assuming a 2.5 %, 5.0 % and 10 % ochratoxin contamination of exported coffee from Latin American countries. The financial losses are significant and fluctuate over time. It seems that the major losses occurred before 2000 and decreased for a while; then increased after 2003. It is expected that with increased food safety vigilance by importing countries more foods will be inspected and detained at ports of entry. Hence, LAC countries are likely to suffer major financial and economic losses from the wine and coffee industries if attention is not paid to monitoring the quality of these products.

Mycotoxin regulations in foods and feeds worldwide and in Latin America

Detailed information on the existence or absence of specific limits and regulations for mycotoxins in human food and animal feed exist in about 120 countries of the world. These regulations exist in 15 countries of Africa that represent approximately 59% of inhabitants on the continent. Twenty-six countries (88% of inhabitants) of Asia/Oceanna, 39 countries in Europe (99% of inhabitants), 19 countries in Latin America (91% of inhabitants) and both the US and Canada in North America

(100% of inhabitants) have specific mycotoxin regulations (van Egmond and Jonker, 2005).

LAC countries are net exporters of cereals and grains. The quantities of grains exported are small. However, certain countries export wheat, processed corn and peanuts. U.S. annual peanut imports (shelled) have been over 55,000 metric tons (MT), and Argentina, Brazil, Mexico, and Nicaragua supply more than 90% of this amount (USDA/ERS). Total Latin American peanut production was approximately 780,000 MT in 2000, and the four countries (Argentina, Brazil, Mexico, and Nicaragua) produced roughly 765,000 MT of that amount (USDA/FAS, PS&D). Among these countries exporting to the United States, Argentina has supplied over 75% of the U.S. import market (Lee et al 2006). Levels of aflatoxin greater than 20 ppb have been found in exported peanuts from these countries. In Brazil high levels of aflatoxin were found in peanuts (Freitas and Brigido 1998).

Although certain measures (promotion of good harvesting practices, grain drying procedures and institution of training programs on aflatoxin control) are already being taken in some Latin American countries to control aflatoxin in crops, there is still a great need for programs to control the occurrence of mycotoxins in maize and wheat products used as human and animal food in the region, and to standardize feasible analytical techniques for mycotoxin determination in crops and by-products. In Latin America, harmonized aflatoxin regulations exist in MERCOSUR, a trading block consisting of Argentina, Brazil, Paraguay and Uruguay (FAO, 2003). Aflatoxin regulations are mostly set for total aflatoxins. Other countries in the region indicate that they follow MERCOSUR regulations. Uruguay has the most detailed mycotoxin regulations, including limits for ergot alkaloid in feeds.

Mycotoxin regulations, US, European Union (EU) and Codex: Effect on trade for LAC

The US standard for aflatoxin is 20 ppb for human foods and animal feeds (corn and other grains) intended for immature animals or unknown destinations. The level is 100 ppb in corn or grains for breeding or mature animals, 200 ppb for finishing swine and 300 ppb for finishing beef. In January 1999, the European Union harmonized its aflatoxin regulations. The level set for raw peanuts is less than 15 ppb of total aflatoxin and no more than 8 ppb of AFB_1 (Dohlman, 2003). The aflatoxin level in processed products must not exceed 4 ppb of total aflatoxin and 2 ppb of AFB_1). Wu (2004) pointed out that the nations most likely to be affected by tighter mycotoxin standards are China and Argentina. Argentina is the third top corn and peanut exporting country worldwide after the US and China. Hence, Argentina will experience serious economic losses (estimated at US $70 million annually) with increased mycotoxin standards in corn and peanuts. The aflatoxin level set buy Codex for raw peanuts intended for further processing is 15 ppb and for human food is 30 ppb (Dohlman, 2003).

Latin American economies must meet export standards regarding mycotoxin contamination in order to sell their produce. In order to meet export standards regarding mycotoxin contamination, Latin American economies often export the highest quality and safest foods leaving food of poorer quality for local consumption. Higher concentrations of mycotoxins have been found in maize for domestic consumption than in maize for export in the region (Cardwell et al. 2001). This increases the health risk to the people of these exporting countries. Although LAC countries consume a lower percentage (37-43%) of cereals as a percentage of total energy than developing countries in Asia (75.6%), North Africa (62.7%), and sub-Saharan Africa (48.4%), they consume a higher proportion of cereals than industrialized countries such as the U.S. and Canada (24.4%; Scussel, 2004). The populations in these countries are therefore likely to be highly exposed to mycotoxin contamination in food unless special precautions are taken to control contamination and monitor levels in food intended for domestic consumption.

Conclusion

Major Latin American crops (maize, wheat, soybean, peanut, beans and rice) are all highly susceptible to mycotoxin contamination. These crops form a major part of the diet and some are important export items. Wine and coffee are also important exports items that are subject to mycotoxin contamination. Several studies conducted in different countries in the LAC region have shown high levels of mycotoxin contamination in these crops and produce that affect export and the economy of the region. Since maize (in the form of tortillas or otherwise) account for nearly 50% of food consumed annually in Mexico and the major portion of food consumed in other LAC countries, especially among the lower socioeconomic groups, significant human dietary mycotoxin exposure occurs in the region with undetermined health effects. A factor that further aggravates the situation is that in order to meet mycotoxin regulatory standards established by industrialized countries such as the US and those in the EU, LAC countries often export the best quality food leaving food of poorer quality for domestic consumption. Initial studies conducted in humans in Latin America show that there is exposure to aflatoxin with detection of the aflatoxin B_1 biomarker in blood. Thus, mycotoxins pose a major threat to the health and economy of the LAC region. The region is likely to suffer great economic losses as awareness of the health effects of mycotoxins increases and regulations on imports by industrialized countries become more stringent. The LAC region needs to expand and increase efforts to lower the economic and health impacts associated with mycotoxin contamination of foods. It should increase awareness among food producers and handlers of practices that would minimize mycotoxin contamination of crops, encourage adoption of good agricultural and manufacturing practices, and define and enforce regulatory standards.

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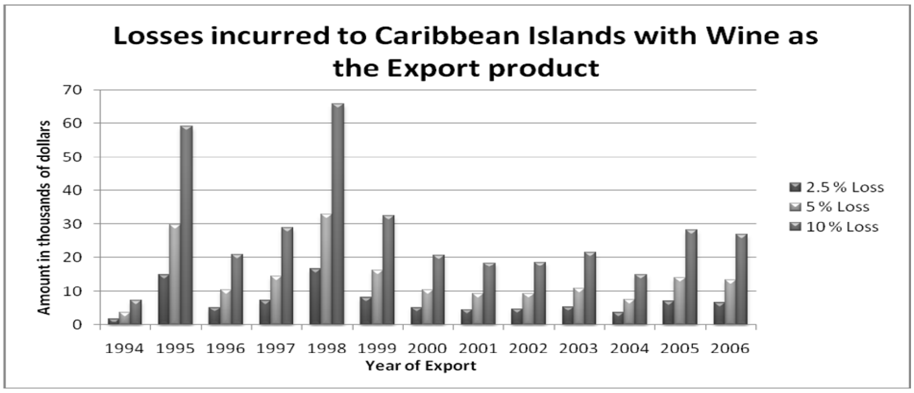

Figure 1: Export losses from wine assuming ochratoxin contamination of 2.5%, 5% and 10% for Caribbean Islands, 1994 to 2006.

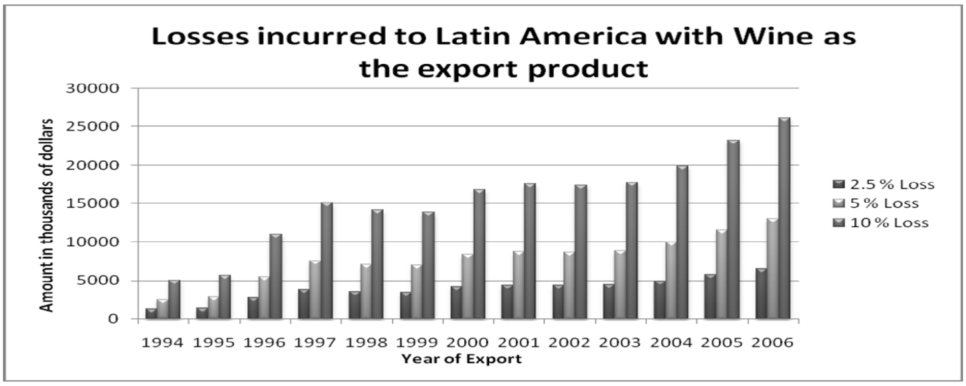

Figure 2: Export losses from wine assuming ochratoxin contamination of 2.5%, 5% and 10% for Latin America, 1994 to 2006.

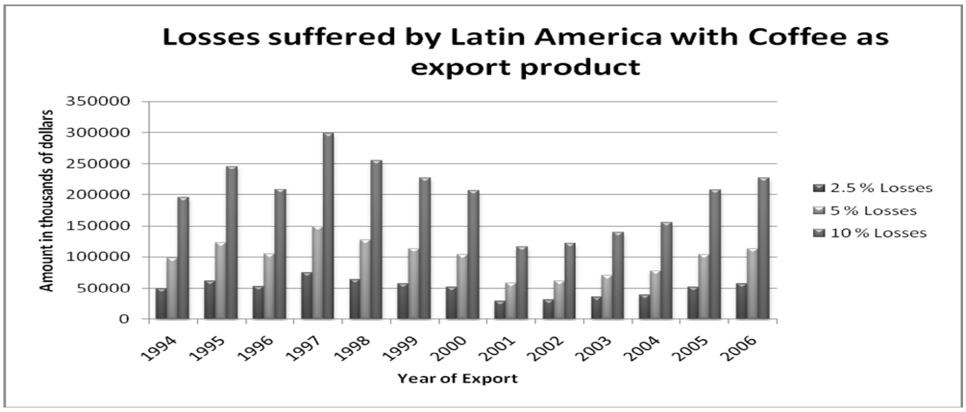

Figure 3: Export losses from coffee assuming ochratoxin contamination of 2.5%, 5% and 10% for Latin America, 1994 to 2006.